Multi-Layer Insulation for the Alpha Magnetic Spectrometer

Guidelines

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Multi-Layer Insulation for the Alpha Magnetic Spectrometer

GUIDELINES DOCUMENT

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ACRONYMS AND ABBREVIATIONS

ADP	Acceptance Data Package
AMS	Alpha Magnetic Spectrometer
ATS	AMS Task Sheet
CCB	Configuration Control Board
CO_2	Carbon Dioxide
CTSD	Crew and Thermal Systems Division
DV	Designated Verifier
EA	Engineering Directorate
ESA	European Space Agency
ISS	International Space Station
JSC	Johnson Space Center
MLI	Multi-layer Insulation
NASA	National Aeronautics and Space Administration
PET	Polyethylene Terephthalate (Mylar)
PIH	Payload Integration Hardware
PSA	Pressure Sensitive Adhesive
PTFE	Polytetrafluoroethylene (Teflon)
PVU	Prototype Verification Unit
RH	Relative Humidity
SPI	Stitches per Inch
T	Temperature
TCS	Thermal Control System
VCM	Volatile Condensable Material
Xe	Xenon

1 INTRODUCTION

1.1 PURPOSE

This document provides the guidelines for the fabrication, handling, storage, and repair of multi-layer insulation (MLI) for the Alpha Magnetic Spectrometer Project. The contents of this document should be used as the basis for the manufacturing and integration of all MLI on the Alpha Magnetic Spectrometer – 02 (AMS-02).

1.2 SCOPE

This document delineates the requirements for the fabrication, containment, storage, installation, repair and inspection of MLI blankets used on the AMS-02 Payload. Guidelines for materials selection, operational and non-operational environments and design and construction standards are also included in this document.

1.3 MULTI-LAYER INSULATION FOR THE AMS PROJECT DESCRIPTION

In accordance with JSC 29789, Project Technical Requirements Specification for the Alpha Magnetic Spectrometer – 02 (AMS-02) Payload Integration Hardware (PIH), thermal blankets will be used in conjunction with the thermal control system (TCS) to protect AMS-02 components from temperature extremes. Standard NASA MLI will be used for fabrication of the thermal blankets. Standard MLI blankets are high-performance insulators which are made of multiple layers of materials that retard the flow of energy due to radiation heat transfer. They are usually made of a plastic film (polyester or polyimide) with vapor deposited layers of metal (most commonly aluminum) on one or both sides of the plastic film to form reflector layers. These reflectors are separated by materials with low thermal conductivity. Multi-layer insulation requires an atmospheric pressure of less than 10^{-5} Torr to prevent convection and gas conduction between the reflector layers. In general, the MLI is externally protected from UV, atomic oxygen, and mechanical stresses by a Teflon-coated fiberglass cloth. A single metallized polyimide (Kapton) layer with the metal facing inward is placed just under the fiberglass cloth to act as a light block.

1.4 APPLICABILITY

The elements of these design guidelines must be observed by engineers and technicians who design and manufacture MLI blankets for installation on AMS-02.

If compliance to these guidelines is not possible, the AMS-02 waiver and deviation process shall be used to document the non-conformance. Waivers and deviations must be approved by the AMS Configuration Control Board (CCB).

Revisions and changes to this document shall be made in accordance with JSC 27542, Alpha Magnetic Spectrometer – 02 (AMS-02) Configuration Management Plan.

2 REFERENCE DOCUMENTS

Applicable Documents

JSC 27296	Project Plan for the AMS-02
JSC 27542	Alpha Magnetic Spectrometer – 02 (AMS-02) Configuration Management Plan
JSC 63123	Alpha Magnetic Spectrometer – 02 (AMS-02) Assembly and Testing Integration Plan
JSC 63164	Quality Management Plan for the Alpha Magnetic Spectrometer (AMS-02) Experiment
NSTS-21000-IDD-ISS	Space Shuttle Program-to-Space Station Program Interface Definition Document

Reference Documents

NASA/TP-1999-209263	Multilayer Insulation Material Guidelines
KSC KTI-5212	Material Selection List for Plastic Films, Foams, and Adhesive Tapes

Requirements Documents

JSC 29789	Project Technical Requirements Specification for the Alpha Magnetic Spectrometer – 02 (AMS-02) Payload Integration Hardware (PIH)
JSC 28792	Alpha Magnetic Spectrometer – 02 Structural Verification Plan for the Space Transportation System and the International Space Station
SSP 30245	Space Station Electrical Bonding Requirements

3 REQUIREMENTS

This section presents the requirements that are considered in delineating the guidelines for the MLI blankets. Details about the MLI blankets that meet the defined requirements are given in section 7, Materials Specification.

3.1 OPERATIONAL REQUIREMENTS

The following paragraphs provide the operational requirements that are applicable to all MLI blankets used on the AMS-02 Payload.

3.1.1 Thermal Environment

The MLI blankets shall be designed to withstand the thermal extreme conditions of -150º C to + 120º C. Verification shall be by test or analysis.

Rationale 1: For unproven materials, tests shall be conducted to demonstrate that the materials meet the above thermal range limits.

Rationale 2: For proven materials, analysis should be sufficient to establish that this requirement is met.

3.1.2 Depressurization and Repressurization Rates

The MLI shall withstand exposure to rapid depressurization or repressurization rates of NSTS-21000-IDD-ISS, Sections 10.6.1.2 (Depressurization) and 10.6.1.3 (Repressurization). Verification shall be by test or analysis.

Rationale 1: For unproven materials, the material composition must be shown to meet this requirement.

Rationale 2: For proven materials, analysis should be sufficient to establish that the requirement is met.

Depressurization rate charts are provided in Figures 1 and 2.

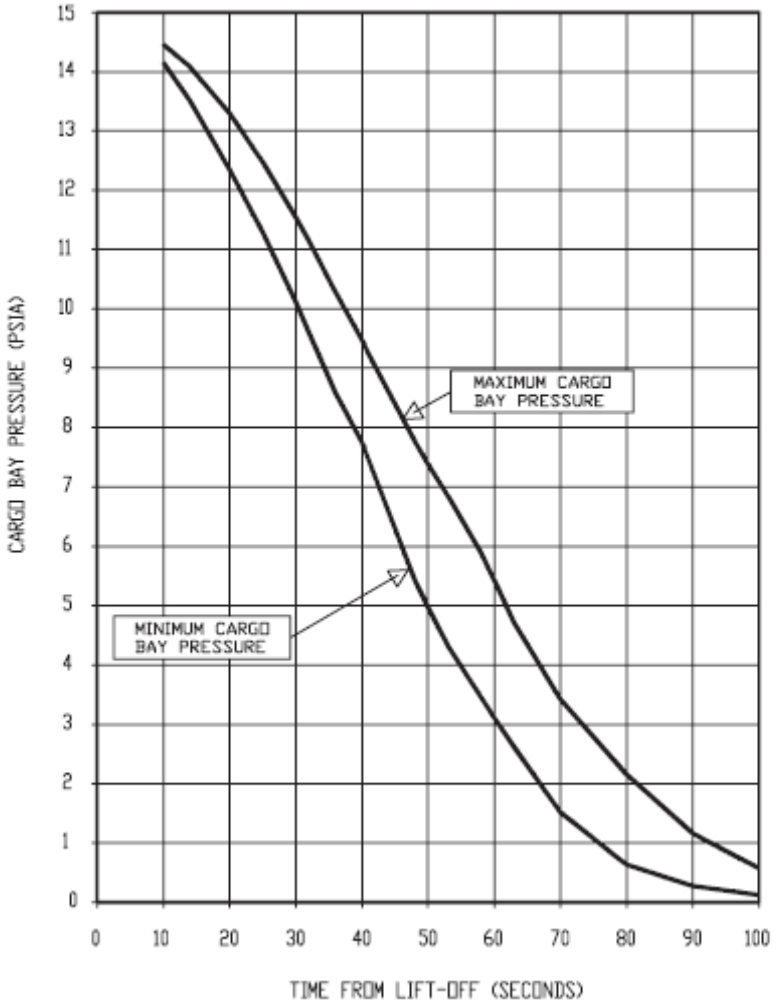

Figure 1: Orbiter Cargo Bay Internal Pressure History during Ascent

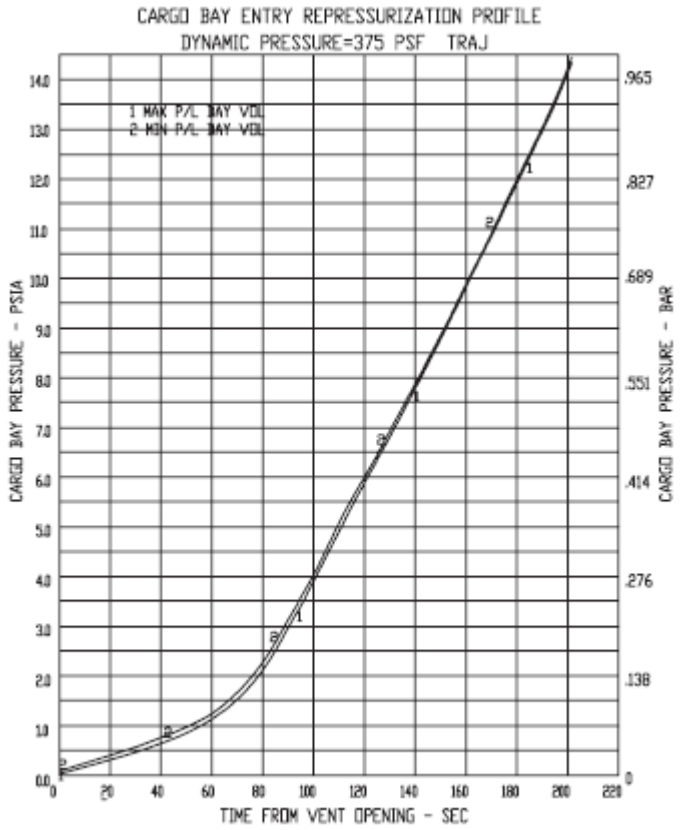

Figure 2: Entry Phase Cargo Bay Internal Pressure Profile

3.1.3 Radiation

MLI blankets that are directly exposed to UV radiation and atomic oxygen shall have a UV radiation and atomic oxygen resistant outer cover.

3.1.4 Solar Electromagnetic Radiation

MLI exposed to the entire solar electromagnetic spectrum shall not embrittle or show significant changes in physical properties during its useful life as defined in paragraph 3.4.1.

3.1.5 AMS Test Configurations Compatibility

The MLI blankets shall be designed to meet the requirements of all AMS test configurations (e.g. test beams, EMI test). The MLI designer shall work with the AMS Collaboration to determine the AMS test configuration needs and shall implement in the blankets design all of the necessary features.

3.2 QUALITY ASSURANCE PROVISIONS

The MLI shall be designed and fabricated in accordance with JSC 63164, Quality Management Plan for the Alpha Magnetic Spectrometer (AMS-02) Experiment.

3.3 NON-OPERATIONAL REQUIREMENTS

3.3.1 In Fabrication Handling

Construction and assembly of the AMS MLI blanket panels will be done in a conventional ISO Class 8 clean room. In addition to construction, including joining panels together and assembly, disassembly or testing of MLI blankets will be performed in a work area that has minimal dust, particulate material, and condensate fumes. All tools, work tables, equipment, templates, holding fixtures, sewing machines or other structures that may contact the MLI must be cleaned before use with a solvent having a nonvolatile residue not exceeding 0.02 g/L. Compatibility of solvents with MLI materials and surfaces that may contact MLI materials must be assessed before use. Work tables and sewing machines should be protected with clean protective covers when not in use.

Workers must wear clean laboratory smocks, powder-free latex gloves (or clean white gloves) and footwear when handling and working with MLI. Clean room clothing will be kept in the laboratory change/locker area when not in use. Appropriate lint-free disposable protective clothing and footwear may also be used. Large pieces of equipment being moved into the clean room must be thoroughly vacuumed prior to entry.

3.3.2 Storage

Raw materials are to remain in their protective packaging until ready for use. Remove the materials from the protective packaging in the clean room just prior to blanket fabrication. When not in use, cover or re-bag these materials to maintain cleanliness. During nonworking hours, cover blankets in fabrication with non-contaminating plastic sheets. Purge all finished blankets with dry nitrogen and double bag the blankets in protective packaging with heat-sealed edges for storage. Do not open packaging that contains Class I (flight hardware) MLI blankets in an area that is not environmentally controlled.

Raw materials and completed blankets should be stored at temperatures between 10° C – 35° C (50° F – 95° F) to the maximum extent practicable. Moisture absorbing desiccant packs and a humidity indicator may be used between inner and outer storage bags to control and monitor humidity levels during storage.

When blankets are removed for use, perform an inspection of the protective packaging and the blanket for discoloration and damage that may have occurred during transportation or storage.

3.3.3 Handling during Installation

The flight blankets must be removed from their protective packaging in a clean area.

Note: Use of a standard clean room or equivalent is only requested for MLI blanket fabrication. Installation of the manufactured blankets does not require standard clean room or equivalent conditions, however blankets should be installed in a work area that is visibly clean and free from particulate matter.

3.3.4 Repair

Repairs to damaged blankets before final installation on the AMS-02 Payload should be done in controlled clean area. Repair to blankets during and after assembly may be done on the assembled article if the location and extent of damage permits such a repair. In all other cases, the MLI should be removed for repair or replacement.

Small cuts or abraded areas on metallized surfaces may be repaired with a contact-adhesive aluminized tape free of wrinkles. Verify that the shelf life of the pressure sensitive adhesive (PSA) tape is within limits before use. While making repairs, avoid entrapment of bubbles, streaks, and foreign material under the tape.

The bagged MLI blankets must be transported in crates sized to hold the blankets flat in the case of small panels or specifically designed to hold more complex shapes.

3.3.5 Late Access Points

The MLI blankets shall be designed to meet all late access requirements. The MLI designer shall work with each detector provider to determine all late access needs and shall implement in the blankets design all of the necessary features.

3.4 MAINTAINABILITY AND RELIABILITY

3.4.1 Useful Life

The on-orbit life expectancy of the AMS-02 MLI blankets should be no less than 5 years in operational condition, and no less than 15 years in non-operational condition. In addition, the AMS-02 MLI blankets should meet ISS contamination requirements as long as the payload is on-orbit.

3.4.2 Shelf Life

The shelf life of the AMS-02 non-reinforced (with no adhesive) MLI blankets should be at least 15 years from the date of manufacture in clean environment and while being stored in sealed protective packaging under controlled storage conditions. Strong, durable protective film as listed on NASA-KSC KTI-5212, Group 1 should be used for MLI packaging. Shelf life should be guaranteed from date of manufacture when MLI is stored in its original container between 50° F and 95° F (10° C and 35° C) and at 50% relative humidity or less.

3.4.3 Acceptance

Acceptance shall be by review of design and by inspection.

The following CHECK LIST shall be performed for MLI incoming inspection:

1. Verify that the Shock Recorders outside the MLI container have not been activated
2. Verify that no damages are present on the MLI container
3. Verify the presence of desiccant bags inside the MLI container
4. Verify the presence of the shipping documentation, in particular
    a) Delivery notes with the Deliverable Item List

b) Blankets Inspection Sheet

c) Hardware Acceptance Data Package

NOTE: Items a) and b) are mandatory

5. Verify thermal blankets do not show:

- Particular Contamination
- Scratches on the surfaces/coatings;
- Mechanical damages in the foils/groundings

6. Verify the respective blanket has been manufactured in accordance with the respective template and all additional instructions provided by the manufacturer. In detail, verify blanket dimensions, the location of attachment points, slits, flaps and holes in the blanket

7. Verify the mass of the blanket meets mass requirements. Record the measured mass value on the Blanket Inspection Sheet

8. Verify marking tag correct position and references. Marking tag shall be located on the backside of the blanket. Verify blanket S/N, Model, Part No.

9. Verify the blanket lay-up conformance with design on the marking tag (number and type of layers)

3.4.4 Documentation

Documentation shall be provided in accordance with JSC 63164, Quality Management Plan for the AMS-02 Experiment, Paragraph 5.11, Documented History.

All integration work on the MLI blankets, including fit-check activities, shall be documented with an AMS Task Sheet (ATS) to maintain full control over the process. The ATS shall be reviewed by NASA. The ATS shall fully reflect all the integration steps and in case the scope of work changes or the work cannot be performed as indicated on the ATS, an ATS Modification Sheet (MOD) shall be written and approved by a NASA DV at CERN or by NASA QA.

The ATS shall include the following set of information as a minimum:

a. ADP reference

b. Blanket name, Part Number, S/N

c. Details of bonding procedure (glue part number, lot number, expiration date, any surface preparation process)

d. Information on the routing of bonding leads, grounding point locations and grounding H/W to meet grounding requirements

e. Grounding measurements sheets

f. Fixation methods (i.e. lacing, Velcro)

g. In case of a fit-check activity information on flaps, slits, modification performed

h. Blankets integration steps

i. Open work list

The ATS is mainly intended as an integration procedure and shall be filled in during integration activities by the responsible engineer or technician.

4 MATERIALS SPECIFICATIONS

The multi-layer reflective insulation blankets shall be made of metallized plastics such as aluminized polyester film.

4.1 MLI STRUCTURE

A typical MLI blanket should include:

- **Standard Blanket Layers**[1]
  - – Outer cover
  - – Light Blocker
  - – Reflector layers
  - – Separator layers
  - – Inner cover
- **Threads**[2]
  - – Non exposed seams
  - – Exposed Seams
- **Adhesives**
- **Adhesive Tapes**
- **Hook-and-Loop Fasteners**
- **Laces and Hand Ties**
- **Buttons**
- **Grommets**

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[1] Perforated or porolated reflector layers (15-20 for long term use). Actual number of reflector layers shall be specified by the end user (Detector or Subsystem Group).

[2] The following guidelines should be observed for the joining of MLI materials using sewn seams

- o Minimal number of seams to prevent heat shorts
- o Low stitch density for sewn seams: 4 to 8 stitches per inch (SPI)
- o Staggered seams
- o PTFE (Teflon) coated glass thread for seams exposed to the environment

4.2 ELECTRICAL BONDING AND GROUNDING

Electrical bonding and grounding will be provided by metallized tape and/or grommets

A. Resistance of grounding assemblies (per NASA/TP-1999-209263 and SSP-30245):
    a. Resistance from ground to spacecraft structure shall be less than (<) 1 Ohm
    b. Resistance from aluminized surface to ground shall be less than (<) 5,000 Ohms
    c. An Ohmmeter shall be used to measure the above resistance.

B. Quantities of grounding assemblies per blanket is based on surface area (S.A.):
    a. S.A. <100 cm^2: No grounding assemblies
    b. 100 cm^2 < S.A. < 4 m^2: Two (2) grounding assemblies
    c. 4 m^2 < S.A.: > Two (2) grounding assemblies, as determined from the resistance measurement with the Ohmmeter, such that the minimum resistance requirement defined above is complied with.

C. Aluminized Glass Cloth Outer Layer/Light Block:
    a. The aluminized surface of the first reflective layer shall face the aluminized side of the glass cloth without any intervening material (scrim). This intermittent, uncontrolled contact is adequate for grounding the outer layer.

The number of grounding assemblies required must be determined from the resistance measurement with the Ohm meter. Grounding assemblies shall not keep blankets from meeting thermal requirements. Ground locations shall be at least 2.54 cm (1 in.) away from other fasteners, and the blanket assembly may not be welded together in the grounding area.

Grommets shall be made of corrosion resistant steel without coating as specified in NASA/TP-1999-209263. The bolt must pass through a flat washer, an eyelet terminal, the blanket, another flat washer, a lock washer, and a lock nut. A single conductor wire of length determined by the application must be crimped to the eyelet terminal and attached to the ground. Use a 22 gauge grounding wire insulated by Teflon.

The bonding leads (from blanket to the structural side) shall be routed and fixed with Kapton tape separately.

The length of the bonding leads shall be recorded on the Integration Sign-off sheets.

The structural bonding leads and the blanket bonding leads shall be connected and secured for each grounding wire.

Each Grounding point location shall be identified in the integration procedure (i.e. ATS) and approved by the AMS collaboration.

Super Koropon shall be applied **along the edge** of each grounding point to prevent corrosion in moist atmosphere on the ground. The grease shall be **applied around the periphery of the joint - after assembly - and not inside or between layers of the joint. Super Koropon lot and expiration date shall be suitably recorded.**

The following hardware data regarding tools for fastening grounding screws shall be recorded in the relevant sections of the installation ATS and APD:

- torque wrench calibration data
- part and lot number for bolt
- part and lot number for washer
- running and final torque

4.3 VENTING

MLI blankets should be designed so that all trapped gases can be vented to the atmosphere within 48 hours after launch. The vent paths should not provide a return path for sunlight.

4.4 STANDARD MLI

Typically MLI blankets have a protective outer cover, a series of reflector layers alternating with separator layers, and an inner layer. A light block layer is usually added to blankets that are fully exposed to the environment. The cover and light block layers may be combined into one layer of aluminized glass fiber fabric if this material is encapsulated with additional layers of other material on the aluminum side.

The materials listed in tables 1 and 2 are acceptable for use in AMS-02 blankets. Other acceptable materials are listed in ESA PSS-01-701.

Table 1: Typical MLI Lay-up Materials

Layer	Material	Applicable Specs	Suggested Vendors	Product Name
Cover	Glass fiber fabric	MBO135-027	Bron Tapes	Beta fabric 500F
Light Block	Aluminized polyimide		Dunmore Sheldahl Orcon	
Cover/Light Block	Aluminized glass fiber fabric	STM0809-01	Dunmore	800 Dun-MET Beta Cloth (500F)/Al
Reflector	Aluminized PET two sides Aluminized PET one side	MDAC STM0691, type II, class 1, grade A	Dunmore Sheldahl Orcon	
Inner Layer	Aluminized reinforced polyimide	MDAC STM0691, type II, class 2, grade B	Dunmore Orcon	
Separator	PET scrim Nomex scrim		Apex Mills Stern & Stern J. P. Stevens	

Table 2: Typical MLI Joining Materials

Layer	Material	Applicable Specs	Suggested Vendors
Exposed Threads	Fiberglass coated with PTFE	MIL-C-20079, type III, class 6	Synthetic Threads
Non-exposed Threads	Nomex	MIL-T-43636, Type II, Size E	Synthetic Threads Eddington Thread
Adhesive	30 NF**		3M
Tapes	PSA Kapton tape PSA aluminized mylar tape		3M
Lace	PTFE Coated fiberglass braided lacing tape		W.F.Lake

**Use 30 NF in small amount as edge lock.

4.5 MLI BLANKETS FABRICATION

After initial measurements and patterns of each MLI blanket are made, a designer should review the design details and use the pattern to develop a CAD model of the blanket and produce the fabrication drawings, followed by installation drawings, and the final drawings. The following steps are generally followed in MLI blanket fabrication.

Steps in MLI Blanket fabrication

1) Design: At the beginning of the design phase a "concept design sketch" is requested.
2) Review MLI Design: This conceptual design shall be reviewed by NASA experts and, once approved, shall be the starting point for the blanket detailed design. Tight blankets shall be avoided. This is under the assumption that final tailoring of the blankets might be needed to fit the blankets to "late hardware".
3) MLI CAD Modeling: Once the "concept design sketch" is reviewed the MLI blankets design shall be completed on AMS CAD models (under AMS Mechanical Integrator configuration control). In case of poor fidelity of the CAD model (e.g. cabling not sufficiently represented), the fabrication of a Prototype Verification Unit (PVU) or template to be fit-checked is highly recommended.

4) In cases where a PVU fit-check has taken place, the NASA and detector groups, to whom the MLI blankets apply, shall approve the MLI design, and the evaluation and modification of the PVU.

5) Evaluation and Modification of PVU

6) MLI Fabrication Drawings

7) Installed MLI Drawings

8) Final MLI Drawings must be included in the Acceptance Data Package (ADP).

9) Fabrication of the Flight Units

10) Package for Storage: The MLI blankets supplier shall be responsible for the first blanket integration. Any further dismounting and re-integration of the blankets shall be performed by the AMS collaboration. In case the blankets are removed for general AMS integration needs, the blankets shall be properly removed and stored under the custody of the AMS collaboration.

5 CLEAN ROOM

The MLI blanket panels should be fabricated in an ISO Class 8 clean room or in an equivalent controlled area to reduce risk of contamination that will affect the thermal performance of the blankets. Since the vacuum deposited layer of metal on the reflector layers of MLI blankets is very thin and fragile, it can easily be abraded. This is why the reflector layers shall not be cleaned, and must be kept in the pristine condition they were received from the manufacturer. The standard requirements for an ISO Class 8 clean room are listed in Table 3

Table 3: Standard Requirements for an ISO Class 8 Clean Room

Attribute	Requirement
Particle Count (>0.5μm/ft3)	≤100,000
Particle Monitoring	Automatic counters
Air Conditioning	22º C ±3º C (72° F ±5° F) 45% ±5% R. H.
Air Filtration	Stages No. 1, 2, and 3
Pressure Differential	Positive (higher P in clean room)
Room Air Flow	15-20 air changes/hour
Environmental Controls (T, RH)	Located outside clean room
Airlocks	Required at all entrances
Garment Requirements	Lint-free caps, hoods, gloves, booties
Shoe Cleaner	Vacuum shoe cleaners

6 ATTACHMENT

MLI blankets must be designed to provide positive attachment to AMS-02 structure or to other blankets.
The blanket fixation shall be performed primarily by:

- Velcro
- Lacing

It is highly recommended to avoid using the stand-off method; however in case it is implemented, bonding samples with the stand-off shall be produced. The samples and remaining adhesive mixture shall be kept for traceability purposes. Pull-out and shear-load tests shall be required in case the stand-offs are glued to surfaces whose surface treatments are not covered by the existing MLI supplier qualification reports.

In case stand offs are used, the mounting/dismounting cycles for the clip-washers shall not exceed 20 cycles. In case that it can not be ensured, a visual inspection performed randomly is mandatory prior to launch/test.

All the lacing attachment points shall be tied off in a double knot (a square knot with an extra twist).

A bonding sample with Velcro glued on an aluminum sample shall be produced. The sample shall be kept for traceability reasons. Verify, on the Blanket Historical Record, that the Velcro mounting/dismounting cycles have not exceeded 10 cycles. In case that it can not be ensured, a visual inspection performed randomly is mandatory prior to launch/test.

All the attachment methods shall be approved by AMS collaboration/NASA during MLI design review.

All the gluing procedures and the surface treatment methods shall be approved by the AMS collaboration / NASA and recorded in the installation ATS and

relevant section of the ADP.

7 DELIVERABLES

The following must be specified for delivery with the Class I (Flight) MLI Blankets:

- MLI CAD models
- Installed MLI drawings
- Lacing procedure
- Generic handling procedure
- Certificate of Conformance
- ADP including:
    - Shipping documents/deliverable items list
    - Historical record/logbook
    - Integration sign-off sheets
    - Open work list
- Fit-check procedure in ATS format
- MLI integration procedure in ATS format

Blanket patterns and fabrication drawings may be retained by the manufacturer, but must be made available to the end user upon request.